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SOUTH BASE POND REPORT

The Response of Wetland Plants to Stormwater Runoff From a Transit Base

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EXECUTIVE SUMMARY

The pollutant removal efficiency of a stormwater detention pond can be greatly enhanced by pond conversion to an artificial wetland. Many wetland plant species have the potential to accumulate significant quantities of pollutants associated with urban stormwater runoff, such as heavy metals and petroleum hydrocarbons. Metro's South Base Pond Project investigated the pollutant uptake potential of several wetland plants and the vigor of several other plants in response to variable inundation levels. Of the species studied for their pollutant uptake abilities, *Typha latifolia* accumulated the most of the three target pollutants—lead, zinc, and total petroleum hydrocarbons (TPH). Three plants, *Juncus ensifolius*, *Scirpus cyperinus*, and *Scirpus acutus*, displayed variation in height, basal circumference, and number of stems and inflorescences according to various levels of inundation. These growth parameters increased with greater average water depth.

RESULTS

Pollutant Uptake

The five species of wetland plants focused on in the study, *Typha latifolia*, *Scirpus acutus*, *Iris pseudacorus*, *Eleocharis ovata*, and *Sparganium sp.*, all displayed some capacity to absorb lead, zinc, and TPH. Because of its vigorous growth and large biomass, *Typha latifolia* accumulated the highest concentrations of lead (0.049 g/m^2), zinc (0.467 g/m^2), and TPH (9.96 g/m^2) per unit area of plant coverage. Of the five study species, *Iris pseudacorus* root tissues stored mean levels of petroleum hydrocarbons significantly higher (1,566 mg/kg) than surrounding mean soil levels (652 mg/kg). *Sparganium sp.* had the highest mean concentrations of lead and zinc (79.7 mg/kg and 487.9 mg/kg, respectively) per unit weight of tissue, dry basis.

In comparison with the same species taken from an unpolluted control site, each of the five species at the pond assimilated higher concentrations of lead, zinc, and TPH. This may be associated with higher ambient soil concentrations of lead, zinc, and TPH found at the pond. The root tissues of each of the five species stored levels of lead, zinc, and TPH significantly greater than the shoot tissues. However, in general, soil levels of these pollutants far exceeded the total tissue concentrations for each pollutant.

Biomass

Biomass measurements taken at the end of the growing season for each of the pollutant uptake species indicated that *Typha latifolia* produced the largest biomass per unit area (8.02 kg/m^2) of the five species, followed by *Iris pseudacorus* (3.97 kg/m^2), *Scirpus acutus* (3.13 kg/m^2), *Eleocharis ovata* (0.98 kg/m^2), and *Sparganium sp.* (0.63 kg/m^2). These measurements were used to estimate the pollutant uptake potential per unit area of a single species.

Plant Vigor

Three species of *Juncus*, *Juncus ensifolius*, *Juncus tenuis*, and *Juncus effusus*, and three species of *Scirpus*, *Scirpus acutus*, *Scirpus cyperinus*, and *Scirpus microcarpus*, responded variably to a range of inundation levels.

Juncus ensifolius, *Scirpus acutus*, and *Scirpus cyperinus* increased in two or more vigor measurements (height, basal circumference, number of stems, and number of inflorescences) with greater average water depth. The height of *Juncus effusus* varied significantly with greater average water depth. There was no correlation between vigor measurements and greater average water depth for *Scirpus microcarpus* and *Juncus tenuis*.

Monitoring these six species over a year also revealed seasonal trends in the response of vigor measurements to inundation level. The correlation between variation in number of inflorescences and range of inundation level weakened considerably in the fall/winter months and strengthened in the spring for *Scirpus acutus*, *Scirpus cyperinus*, and *Juncus effusus*. *Juncus ensifolius* and *Juncus tenuis* displayed the same trend between variation in height and range of inundation level.

RECOMMENDATIONS

An artificial wetland should be designed to support persistent and vigorous plant growth to maximize pollutant uptake as well as accommodate stormwater control and storage. The following are summaries of key design, construction, and maintenance recommendations based on the results of the pond project:

- ***Create Low Sloping Banks.*** The wetland should have broad, shallow areas with low sloping banks to provide a large area of optimal conditions for wetland plant proliferation.

- ***Regulate Water Levels.*** Regulate water levels to ensure that plants have a consistent inundation level for maximum growth.

- ***Plant Typha latifolia Near Inflows.*** Because of its strong pollutant uptake capacity and dense, vigorous growth, plant *Typha latifolia* near the inflows to buffer the rest of the wetland from initial inflow velocities and pollutant loadings by reducing flow energy, trapping pollutant-laden sediments, and absorbing pollutants.

- ***Manage the Growth of Typha latifolia.*** Restrict *Typha latifolia* to high pollutant exposure areas by thinning and harvesting. Otherwise, *Typha latifolia* may become a nuisance, excluding other plant species and lowering the diversity and wildlife habitat of the wetland.

- ***Plant a Diversity of Species.*** Attention should be given to maintaining species diversity in the wetland, introducing species for pollutant uptake potential as well as ecological and aesthetic value.

- ***Install Other Pollutant Control Devices.*** In the Puget Sound region, the period of greatest pollutant input (the fall/winter rainy season) occurs when pollutant uptake activity is lowest, when the majority of plants are senescent or dormant. Pre-wetland pollutant control devices such as oil/water separators or pre-settlement basins can resolve this problem.

- ***Plant Perennials and Plants with Long Growing Seasons.*** Plant perennials and annual plants with long growing seasons, such as *Juncus effusus*, throughout the wetland for some degree of pollutant uptake in the fall/winter rainy season.

- ***Create a Deep Forebay.*** Create a deep forebay at the inflow source to facilitate sedimentation, and use floating oil-adsorbing booms to trap surface sheens. These will help mitigate the impacts of the stormwater before it enters the rest of the wetland.

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SECTION 1

INTRODUCTION

The impervious surfaces that facilitate transportation and commerce in urban communities also drastically alter the natural watershed hydrology. Paved surfaces diminish the natural ecosystem's capacity to store and adsorb precipitation. The force of stormwater runoff often causes severe erosion and sediment transport if it is directed without mitigation into the regional watershed and receiving waters (Schueler 1987). Urban stormwater runoff also becomes a major source of nonpoint water pollution as it flushes the residues and wastes of urban activity from the paved surfaces where they accrete.

The byproducts of motor vehicle operation and maintenance contribute significantly to nonpoint water pollution. Petroleum hydrocarbons from fuel, lubricants, solvents, and exhaust; surfactants from cleaning fluids; antifreeze; and heavy metals from fuel additives, body corrosion, tire and brake wear collect on paved surfaces where they become adsorbed by surface dust and eventually washed into the urban watershed during storms (Asplund, et al. 1980). Lead and petroleum hydrocarbons especially show high affinities for surface particulates. From 70 to 95 percent of these pollutants in stormwater runoff can be attributed to the particulate phase (Kulzer 1989, MacKenzie and Hunter 1979, Sheehan 1975). Allowed to pass into receiving waters untreated, the pollutants carried by urban stormwater runoff can result in both immediate and cumulative disruption of aquatic ecosystems (Boyd and Sartor 1972, Galvin 1982).

Heavy metals can cause immediate toxicity in fish and macroinvertebrates as well as accumulate in animal and plant tissues, passing on to the next higher trophic level. Various petroleum hydrocarbons, especially aromatic hydrocarbons, have been implicated as carcinogens, inducing tumors in fish (Stuart and Cardwell 1988). Unmitigated, bulk inflow of stormwater into receiving waters also can cause drastic drops in dissolved oxygen levels and rapid changes in water temperature, often resulting in mass kills of fish and other aquatic organisms (Schueler 1987).

URBAN STORMWATER BEST MANAGEMENT PRACTICES (BMPs)

Numerous approaches exist to treat both the quantity and quality of urban stormwater runoff. Termed best management practices (BMPs), these approaches aim to mitigate erosion and pollution from stormwater with technologies appropriate to site constraints, inflow volumes, and pollutant loads. Stormwater runoff BMPs control erosion and pollutant transport by detaining runoff and regulating its volume. By increasing the hydraulic residence time, initial inflow energy dissipates, and pollutants associated with suspended particles settle out (Birch, et al. 1992).

Basic stormwater-control BMP structures include catchment basins such as storage vaults, pre-settlement basins, infiltration/filtration basins, and wet/dry detention ponds. While short-term retention structures such as storage vaults, dry detention ponds, and pre-settlement basins perform well to control runoff volumes and to remove heavier suspended particles, pollutants associated with finer particles such as excess nutrients, heavy metals, and petroleum hydrocarbons remain suspended and pass into receiving waters. Structures such as wet detention ponds and infiltration/filtration basins can intercept and retain these finer particles through longer detention time, filtration, and soil adsorption (Schueler 1987). The pollutant retention and neutralization potential of longer-term retention basins can be further enhanced by the biofiltration potential of vegetated swales and natural and constructed wetlands. Wetlands alone have shown removal efficiencies of 41 to 73 percent of lead, zinc, and TSS from urban runoff (Martin 1988).

In addition, constructed wetlands not only enhance the overall aesthetics in the urban landscape but also improve air quality through carbon dioxide consumption and oxygen release via photosynthesis. Furthermore, constructed wetlands provide valuable refuge and habitat for wildlife, especially migratory and resident bird populations. Many species of birds and other wildlife rely on these pockets of wetland vegetation for overwintering and reproduction (Adams, et al. 1988).

CONSTRUCTED WETLANDS

The success of a constructed wetland, in terms of outflow water quality, depends on a variety of complex and highly interdependent factors. Surface water hydrology, biological activity, quantity and quality of inflow, soil chemistry, precipitation frequency, and volumes, among other factors, contribute to the outflow quality of a constructed wetland. Temporal variations in these factors result in changes of outflow quality over time. Effective management of a constructed wetland requires a working understanding of the major factors in a wetland system and how they interact (EPA 1988).

The biology of a wetland stands foremost among those factors. The organisms adapted to existence in saturated and submersed substrates define the wetland ecosystem. In fact, the adaptations that enable certain organisms to survive in an aqueous environment also directly and indirectly improve water quality (Guntenspergen et al. 1989). In wetland ecosystems, aquatic macrophytes and associated soil microbes act as primary agents of biofiltration. Roots, rhizomes, stems, and decomposing biomass not only reduce flow and mechanically trap and adsorb suspended particles but also provide a matrix where microbes can thrive and assimilate excess organics, metals, and nutrients (Hammer and Bastian 1989).

In a managed setting, using the biofiltration potential of aquatic macrophytes and associated microbes can provide a means to remediate moderate quantities of pollutants, such as excess nutrients, heavy metals, and petroleum hydrocarbons. The application of wastewater to artificial or natural wetlands has been in popular practice in the United States since the 1970s. However, the deliberate application of stormwater runoff, especially from urban sources, for treatment within artificial or natural wetlands is not yet common practice. Current research literature reflects this disparity, with most of the research geared toward wastewater investigations (Stockdale 1986). This disparity may derive from the late recognition of stormwater as a nonpoint source of pollution in receiving waters and the difficulty of identifying and treating nonpoint pollution sources. In contrast, identifiable point sources of water pollution, such as industrial and municipal wastewater, can be more easily targeted for remediation.

Since the late 1950s, Kathe Seidel of Germany has conducted pioneering research on the ability of certain emergent aquatic macrophytes to accumulate and metabolize organic toxicants. She found that pollutant uptake capacities vary from species to species and among an individual plant's tissues as well. Roots, rhizomes, shoots, and stems all exhibit differential preference for various pollutants, some retaining concentrations that exceed those of the surrounding substrate (Seidel 1976). Such knowledge of aquatic macrophyte pollutant uptake capacities and their environmental tolerances figures prominently in planning constructed wetlands for receiving urban stormwater runoff.